

**Process and Apparatus for Manufacturing Fuel Gas and Liquid Fuels From Trash, Other  
Waste Materials and Solid Fuels**

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Declaration

**SPECIFICATION:**

**TITLE OF INVENTION:**

**CROSS REFERENCE TO RELATED APPLICATIONS:** Subject matter was disclosed in provisional application serial number 60/220, 609 filed at United States Patent Office on July 25, 2000.

**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR**

**DEVELOPMENT:** This invention was NOT made by an agency of the United States Government, NOR under a contract with an agency of the United States Government.

**BACKGROUND OF THE INVENTION:**

**1. FIELD OF THE INVENTION**

The present invention relates to a process for recovering gas and other useful materials from trash, other waste and solid fuels, and, in particular, to a process for recovering oil and gas that can be used as fuels and other materials having economic value. The present invention also relates to an apparatus for recovering gas, oil, and other useful materials from trash, other waste and solid fuels. The process and apparatus of the present invention also have application in other fields, such as oil shale, wood, coalmine waste, tar sands, biomass, peat and coal processing.

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Other known means of producing fuel gas were producer gas sets and water gas sets. A producer gas set was typically a vertical cylinder made of steel. These cylinders were often, but not always, lined with firebrick. Coal or coke was fed into the top of the cylinder either manually or automatically. Air or oxygen, with or without a mixture of steam and/or carbon dioxide, was blown up from down below through the incandescent fuel bed. The air or oxygen reacted with the coal or coke to first form carbon dioxide that in turn reacted with more of the coke or coal and was reduced to carbon monoxide. Carbon monoxide has a heat of combustion of about 300 British Thermal Units (BTUs) per cubic foot. If steam were also blown through the fuel bed, it would also be reduced by the hot coke or coal to carbon monoxide and hydrogen. Hydrogen also has a heat of combustion of about 300 BTUs per cubic foot. In the case of a producer gas set run on air, with steam and/or carbon dioxide and with coke as the fuel, the typical gas produced would have a heat of combustion of about 125 BTUs per cubic foot due to the dilution of the gas with inert nitrogen from the air. If it were run on coal, because of the volatiles distilled off of the coal near the top of the cylinder, the coal would produce a considerably better gas of about 160

BTUs per cubic foot. If pure oxygen were used instead of air, the resultant producer gas typically had 300-500 BTUs per cubic foot.

The gas produced from a producer gas set includes possibly some nitrogen and such combustibles as carbon monoxide, hydrogen, some methane, and, in the case of a gas producer set run on coal, a wide variety of volatile hydrocarbons, including vaporized tar. A gas produced from coke typically includes, aside from the nitrogen which would be in it from the air, approximately one third hydrogen and two thirds carbon monoxide with a minute trace of methane. In the case of gas made from coal, the gas contains considerably more hydrocarbons. The gas produced was often burned straight by drawing it into a furnace or boiler. Otherwise, the gas produced was cleaned and cooled to remove the tar and other readily liquefiable hydrocarbons and fly ash before burning. When the gas from the producer gas set is burned after being cleaned (having the tar removed), hydrogen, carbon monoxide and some hydrocarbons, such as methane, ethane, etc. (particularly, in the case of gas made from coal), are the gases that are primarily burned.

The process of producing a gas from the water gas set process is similar to the producer gas set process in that the machinery is very similar. The difference is that instead of blowing air and steam through the cylinder simultaneously, the water gas set process alternates between blasts of air called "blows" and blasts of steam called "runs". The gases are drawn off by switching valves on the top of the cylinder, so that that blow gases (gases made with just air) go to a waste heat boiler to generate steam, and the run gases (gases made with steam) are put into a pipeline. In the case of a water gas set (or a producer gas set if it's run on pure oxygen), the energy value of the gases is around 300 BTUs per cubic foot or higher. If the gas is made from coal or some other source of hydrocarbons that are cracked in the top of the solid fuel column, the gas has BTU values of approximately 500 BTUs per cubic foot or even higher.

In the 1950's natural gas entered the picture. Natural gas pipelines were installed and natural gas was sold cheaply, which in turn basically persuaded towns to shut down their old gasification equipment (ex: producer gas sets and water gas sets and

coal distilleries). In years past, considerable technology was developed for the processing of coal.

### 3. BRIEF SUMMARY OF THE INVENTION

It is a feature and advantage of the present invention to provide a process and apparatus for recovering gas and other useful materials from trash, waste tires, rendering plant waste, and other waste and solid fuels such as coal, wood, coalmine waste, peat, oil shale, biomass and tar sands. The process of the present invention and a processor of the present invention can advantageously operate on producer gas set cycles or water gas set cycles.

The present invention advantageously modifies and improves technology developed for the recovery of fuel gases from coal for use in the recovery of gas and other useful materials from trash, waste tires, rendering plant waste, and other waste and solid fuels such as coal, wood, coalmine waste, peat, oil shale, biomass and tar sands.

It is another feature and advantage of the present invention to provide a process and apparatus for recovering gas and other useful materials from trash and other waste and solid fuels that also allows for the recovery of oil both from the solids directly and also via catalytically converting the gas into oil.

It is an additional feature and advantage of the present invention to provide a process and apparatus for recovering gas and other useful materials from trash and other waste that also allows for the recovery of aluminum, steel, iron and other metals typically found in trash and other waste.

To achieve the stated and other features, advantages and objects, an embodiment of the present invention provides a process for recovering gas and other useful materials from trash and other waste and solid fuels such as coal, wood, peat, oil shale, biomass and tar sands. The process of the present invention results in the generation of fuel gas and oil, and the recovery of other useful materials with increased yield of oil due to the height of the solid fuel column and low temperatures on its upper end. In a process of the present invention, a stream of trash and other waste materials may be shredded. The stream of trash and waste materials may comprise, for example, paper, plastic materials, glass, metals (ex: iron, aluminum,

etc.) chemical wastes, rendering plant wastes, and tires. The trash stream is preferably passed through a magnetic separator to remove iron and then passed through a special type of separator, known in the art, for removing aluminum and other non-ferrous metals. These recovered metals may be sold to a scrap yard.

The trash stream and/or other solid fuels are then mechanically fed to the top of an apparatus of the present invention, a processor. An auger screw, ram or similar feed mechanism is preferably located at the top of the processor to constantly feed in the trash and/or solid fuel. In another embodiment, the trash and/or solid fuel are fed down into the processor via gravity through a vertical or diagonal shaft that is long enough to be self-sealing.

The processor melts any metals, fuel additives, ash, glass, etc., as it travels down through the processor into a liquid form, which comes out of the processor. A slag tap is located at the bottom of the processor, which allows the hot slag or molten ash (the molten remains of trash, coal, wood, peat, etc., fed into the processor) to be withdrawn from the processor. The materials in the processor may be initially ignited by burning gas or oil at the bottom of the processor at/or near the slag tap. Once materials in the processor are initially ignited, the process is able to operate continuously since new materials entering the processor contact materials that have already been ignited and are also heated by the rising hot gases as the solids fall through the column. Air and/or oxygen is preferably blown into the bottom of the processor through or near the slag tap right over (past) the fluid slag that is pouring out of the processor. There may also be other air or oxygen injection points. By adding some oil, gas, or waste organic liquids to the gas entering the processor and burning it at the same time, the temperature of the gas entering the processor would increase, which would ensure that the slag flows out of the processor fluidly. The fuel gas-air/oxygen mixture would probably be of an oxidizing nature even after complete combustion. In one embodiment of the present invention, the hot slag leaving the processor is continuously poured into molds.

Another gas is preferably injected through the side of the processor approximately halfway up the processor. A mixture of steam and/or carbon dioxide is a preferred gas for injection. The gas injected reacts with the hot carbon from the trash, reducing the

temperature and converting the thermal energy into chemical energy in the form of hydrogen and/or carbon monoxide. Air and/or oxygen can also be added at the same site and/or at different sites.

Gas is preferably drawn out of the top of the processor. Multiple taps may also be placed at varying heights on the side of the processor to draw off gas. The gas produced by a process of the present invention has a different composition and different properties at various heights within the processor. The location of taps on the processor vary on the particular qualities of gas desired. This is particularly useful when used with the water gas cycle. The gas can be run through a turbine or the like to recover energy from the steam and other condensable components of the gas stream before they reach the cooler-scrubber to remove them especially if a blower, eductor or the like is located after the cooler-scrubber to draw the gas through and out of the cooler-scrubber.

The sizes of the various pieces of processing equipment in the present invention are dependent on a number of factors, including the amount of trash and solid fuel materials that is desired to be handled and/or the amount of fuel gas or oil that is desired to be produced. A person of ordinary skill in the art could readily design and select processing equipment of appropriate sizes based on these factors and others. An apparatus of the present invention used in the recovery of gas, oil, and other useful materials from trash and other waste and solid fuels, comprises a processor having an auger screw, a ram or similar feed mechanism or a gravity hopper and shaft at the top, with a slag tap at the bottom. The processor is preferably a large, cylindrical shell, set vertically and lined with a suitable refractory. The cylindrical shell could also be an air-, steam-, water-, or carbon dioxide-cooled metal shell, which can also serve as a gas injection site. It may also have a droppable or detachable bottom. The processor also has a side input, located approximately midway up the cylinder or lower, for the injection of additional gas into the processor. Hot slag may be withdrawn from the processor through the slag tap, through which air, other gases and/or liquid fuels may also be blown into the processor. The processor also has an outlet near its top for withdrawing the fuel gas.

It is also a feature and advantage of the present invention to provide a process and

apparatus for recovering gas and other useful materials from trash, chemical waste, rendering plant waste, and other waste and solid fuels that incorporates fluid withdrawal of the ash in the form of a molten glass-like material that in turn can be cast into molded items, such as patio blocks or fertilizer sticks, allowing the use of trash, solid fuels, etc., having low ash fusion points.

The present invention also provides an advantageous use of waste plastics to recover gas, oil and other useful materials.

It is an additional feature and advantage of the present invention to provide a process and apparatus for recovering gas, oil, and other useful materials from trash and other waste wherein the costs of eliminating the trash and other waste are less than the value of the gas generated by the process.

It is another feature and advantage of the present invention to provide a device that improves the quality of the gas drawn from the processor by passing it through a second processor or like having a hot bed of low volatile solid fuel to decompose any steam, carbon dioxide, oxygenated hydrocarbons, etc., and to crack heavier hydrocarbons in the gas. The gas drawn from the first processor can also be burned with preferably an excess of air/oxygen immediately before being fed into the low volatile fuel bed of the second processor, which in turn converts the steam, carbon dioxide, and heat (both from the combustion of the initial gas-air/oxygen mix and from the excess oxygen reacting with the solid fuel) into carbon monoxide and hydrogen. This second processor, which I call a beneficator, can also be used on gases, vapors, liquids, etc., from sources other than a processor for the purposes of hydrocarbon cracking, destruction of oxygen containing organic compounds such as dioxanes and organic acids, destruction of nitrogen oxides, and reduction of steam, water vapor, and carbon dioxide.

The gas preferably enters a beneficator after leaving the cooler-scrubber or the processor itself. The beneficator, a device of the present invention, operates to remove materials such as nitrogen oxides, organic acids, dioxins, and other undesirable materials from a gas stream. The gas is blown through a hot coke/charcoal bed and is reduced down to carbon monoxide and ordinary hydrocarbons, etc. A beneficator of the present invention may also use a wood

charcoal bed, a bed of chars from lignite or any other extremely low volatile carbonaceous material that can be used as a fuel and other chemical reactant.

Additional objects, advantages and novel features of the invention will be set forth in part in the description that follows, and in part will become more apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention.

#### 4. DETAILED DESCRIPTION

Referring now in detail to an embodiment of the present invention, a process and apparatus are provided for recovering gas, oil and other useful materials from trash and other waste. For example, the present invention may be utilized with solid waste, coal, lignite, peat, tires, wood, coke, biomass, oil shale, tar sands, paper, a wide variety of chemical waste, and a wide variety of other things. The process of the present invention results in the recovery of fuel gas, oil and other useful materials. In the case of tires, plastics or anything with a substantial hydrocarbon content (as opposed to a relatively pure carbon material like coke), the process of the present invention invariably results in a gas having various quantities of hydrocarbons, many of which may be distilled off the top. In that regard, when trash is used in the process of the present invention, considerable quantities of oil may be recovered. Likewise, oil may be recovered when coal, biomass, lignite and various other materials containing hydrocarbons are used as a fuel.

When the gas produced from the process of the present invention is burned hot and the gas contains tar/oil and came from a source like trash or bituminous coal, the gas usually contains at least an additional 40 BTUs per cubic foot based on the presence of the hydrocarbons that are heavy enough to condense normally at room temperature, plus the sensible heat.

The trash used in the present invention preferably also comprises paper, other materials with hydrocarbons content (such as plastics, etc.), and other organic materials. By pre-moving steel and other inorganic materials, the quantity of ash to be removed from the processor is reduced. Further, the pre-removal of inorganic materials also produces valuable byproducts, such as aluminum and steel that can be recycled. For example, the aluminum and steel could be sold to a scrap yard.



The stream of trash and other materials entering the processor of the present invention is preferably shredded, passed through a magnetic separator to remove the iron, and then passed through a special type of separator for removing aluminum and other non-ferrous metals. The removal of metals from the incoming stream would pay for the costs of removal based on the scrap prices of the metals removed and would substantially reduce the amount of slag produced by the processor. Further, removing the metals would also improve the fluidity of the slag because instead of having appreciable quantities of iron oxide and aluminum oxide getting into the slag, the slag would be substantially glass and paper ash, which are more easily fusible. Additives such as glass, sodium silicate, sodium carbonate, potassium carbonate, coal and coal ashes, etc., can be added to make the ash even more fusible.

The stream of trash and other materials entering the processor may further comprise glass. Although glass may be separated from the stream prior to entering the processor, it is preferable to leave it in the stream. Glass is more difficult to remove from a waste stream than metals are because it is not susceptible to electro-magnetism. Further, glass has a very limited market value for scrap whereas metals such as iron, aluminum and copper have considerable value for scrap and are fairly easy to get rid of. If glass goes into the processor, it is processed with the waste papers, the plastics and other materials in the processor. The glass will melt and flow out of the processor with the slag and tends to reduce the fusion point of the slag. The stream of trash and other materials entering the processor preferably comprised plastics. Plastics are useful in the present invention because they have a high volatile content, have high energy, and produce little ash. So consequently, the higher the plastics content of the stream going to the processor, the better it is. Besides improving the quality of the gas by having a large plastics content, it will also improve the quantity of recoverable hydrocarbons that will be coming out in the hot gas stream.

The hot slag or ash leaves the processor as a molten glass-like material. In one embodiment of the present invention, the hot slag or ash is withdrawn from the processor and cast into molds. For example, the hot slag can be cast in to patio blocks and sold. By using the hot slag, additional waste is eliminated and additional revenue

is generated for the operator of the processor. An operator of a processor of the present invention earns money through acceptance fees for taking the trash, the scrap metal value of the aluminum and steel separated from the trash, the sale of the oil and gas produced by the process and the sale of any molded materials produced from the hot slag.

An apparatus of the present invention preferably comprises a processor. The processor is preferably a large, cylindrical shell, set vertically and lined with a suitable refractory. Suitable refractories include, but are not limited to carbon, silicon carbide, magnesium silicate, calcium aluminate, magnesium aluminate, aluminum oxide, magnesium oxide, calcium oxide, and cooled metals. Alternatively, the cylindrical shell could be an air-cooled, steam-cooled, water-cooled or carbon dioxide-cooled metal shell, which can also serve as a gas injection site or boiler. Trash is mechanically added to the top of the processor after typically first being shredded and having the metals removed from it magnetically, or the trash is added whole. An auger screw or similar feed mechanism preferably located at the top of the processor to constantly feed in trash. Alternatively, the trash, whole or shredded, is dumped down a gravity fed shaft. The shaft is preferably long enough to be self-sealing. Persons of ordinary skill in the art could readily determine an appropriate shaft length that is self-sealing. A self-sealing shaft is advantageous because it could also act as a pressure relief valve for the processor if necessary.

The bottom of the processor is preferably heavily lined with refractory and would have a slanting slag tap. The internal bottom and slag tap of the process may be similar to a cupola or blast furnace, with a fixed, a detachable and/or droppable bottom. The slag tap would preferably have air and/or oxygen blown in through it. A fuel gas or liquid fuel may also be added to the slag tap.

The air and/or oxygen are preferably blown into the bottom of the processor through the slag tap right over the fluid slag that is pouring out of the processor. By adding some oil, gas or waste organic liquids to the air/oxygen entering the processor and burning it at the same time, the temperature of the gas entering the processor would increase, which would ensure that the slag flows out of the processor fluidly. The mixture would be of an oxidizing nature even after complete combustion. As

noted above, in a preferred embodiment, the slag leaving the processor would typically go directly into molds. The molds may, for example, form the slag into patio blocks, or fertilizer sticks.

The processor bottom operates at extremely high temperatures because it has to be hot enough to melt glass, ash and other materials into slag. For example, the lowest part of the processor may operate at temperatures greater than 2500 degrees Fahrenheit. If oxygen is used as the gas entering the processor, the temperature in the processor may be greater than 4400 degrees Fahrenheit. Oxygen is preferable to air for use in the apparatus and process of the present invention. Oxygen operates more efficiently than air and increases the quality of the output fuel gas because it is not diluted with nitrogen, whose presence reduces the BTU value of the gas.

Different chemical and thermal activities are taking place at different heights within the processor during operation. Thus, taps can be placed at various heights on the processor to draw off gases having different compositions and different properties. The bottom portion of the processor operates as a very hot oxidizing combustion situation, which burns out the remaining carbonaceous materials. The carbon is on the descending column of solid fuel (e.g., the trash) within the processor. The processor melts the ash, glass, etc. into a liquid form, which comes out of the processor. Moving up from the bottom portion within the processor, the temperature falls as carbon dioxide and water vapor produced in the first combustion reaction react with the hot carbon it comes in contact with forming additional carbon monoxide and hydrogen.

In a preferred embodiment of the present invention, at a point higher up in the processor (i.e., above the bottom portion), a gas is injected through the side of the processor. A mixture of steam and carbon dioxide is a preferred gas for injection. Steam or carbon dioxide alone may also be injected. A mixture of air, steam, oxygen and / or carbon dioxide may also be injected. Exhaust from engines, furnaces, turbines, boilers or other process equipment located nearby may also be injected through the sides of the processor. The injected carbon dioxide and steam mixture reacts with the hot carbon from the trash reducing the temperature further and

converting the thermal energy into chemical energy in the form of hydrogen and carbon monoxide. Any air or oxygen injected tends to increase the temperature. As the gases rise through the column, they also destructively distill the plastics, paper and other materials within the fuel bed, reducing them to basically a coke-like material. This reduction of plastics, paper and other materials liberates more gases, which are basically combustible, and also recoverable liquid hydrocarbons that distill out with the hot gas.

Gas is preferably drawn out of the top of the processor. However, taps may be placed at varying heights on the processor to draw out gases having different compositions and different properties.

Besides being able to operate on a producer gas cycle as described above, a processor of the present invention can also be operated on other cycles, such as water gas cycle. A water gas cycle would typically draw off blow gases at a lower level (a lower height in the processor) than the producer gas cycle. The run gases would be still drawn off of the top so that all of the oil and rich hydrocarbon gases made from the upper layers of the fuel bed via destructive distillation would only go off with the run gases and not the wasted by going off in the blow gases.

After leaving the processor where they are formed, the hot fuel gas and oil / tar vapor mix can either be fed hot into suitable burners in a furnace or boiler where it is burned, both gases and oil vapors, or it can be drawn through a cooler and scrubber or like, to remove and recover the oil / tar which can then be used or sold separately.

The cooled, washed gas preferably next enters a device of the present invention known as a beneficator, which further improves the quality of the gas. The beneficator is preferably a vertically set, metal cylinder. Alternatively, the beneficator may be diagonally set. The beneficator is preferably used to remove undesirable materials from a lower grade gas. For example, the beneficator operates to remove materials such as sulfur oxides, nitrogen oxides, organic acids, dioxins, carbon dioxide, steam and other undesirable materials from a gas stream. In the present invention, gas drawn from the processor preferably enters the beneficator after leaving the cooler-scrubber. The gas is blown through a red to white-hot coke bed and is reduced down to carbon monoxide, nitrogen, hydrogen and ordinary light



that can be processed into oil, motor oil, fuel oil, diesel fuel and gasoline. The materials molded from the hot slag, such as patio bricks, may be sold for profit. Finally, the aluminum, steel and other metal separated from the trash stream may also be sold for value.

The fuel gas may also be passed through a Fischer Tropsch catalyst to make even more oil or through a methanol catalyst to make methanol, or through a Noble metal or similar catalyst to make ammonium oxalate and/or ammonium formate. The Fischer Tropsch catalyst converts a mixture of hydrogen and carbon monoxide into oil and a by-product of either water vapor or carbon dioxide depending on which catalyst is used and its operating conditions.

Various preferred embodiments of the invention have been described in fulfillment of the various objects of the invention. It should be recognized that these embodiments are merely illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention.

## 5. BRIEF DESCRIPTION OF THE DRAWING

The drawing shows an embodiment of a trash/other waste/other solid fuel processor and also, as modified in the part of the "description of the preferred embodiment" describing the "beneficator", the beneficator.

## 6. DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, reference numeral 10 generally identifies my trash, other waste material, and solid fuel processor comprising a vertical shaft 11 into which trash, other waste and/or solid fuel are fed in to from fuel hopper 12 via auger 13. After leaving the auger 13, the fuel piles up in slowly descending fuel bed 14 where it is gradually heated by contact with the solid fuel, etc., beneath it, and also by the hot, gases and vapors rising up from down below and going through the solid fuel, drying it, and destructively distilling it. As the gases, vapors, and steam rise, they eventually reach gas and vaporized oil pipe 15 and exit vertical shaft 11 through pipe 15. Meanwhile, the upper solid fuel in fuel bed 14 continues to descend, and is heated to over 1000 degrees Fahrenheit, around which point it begins to react with the steam being injected into vertical shaft 11 at steam ports 16, forming hydrogen, carbon

monoxide, and possibly some carbon dioxide, absorbing sensible heat in the process. After the solid fuel passes by steam ports 16, it begins to react with preheated air, being injected into vertical shaft 11 via air injection ports 17 according to the reactions:  $O_2 + 2C \rightarrow 2CO$  plus heat;  $O_2 + C \rightarrow CO_2$  plus much heat; heat +  $CO_2 + C \rightarrow 2CO$ . The nitrogen, of course, remaining generally unreacted. (Any traces of nitrogen oxides formed are immediately destroyed by reacting with the hot carbon monoxide, carbon, etc.) The temperature in this region of the vertical shaft, as well as farther down below are extremely hot, generally well over 2500 degrees Fahrenheit, and often well over 3000 degrees Fahrenheit, causing the ash, together with any additives, such as sodium carbonate, potassium carbonate, sodium silicate, glass, etc. to fuse into a molten ash, slag, or man made lava which flows out of the bottom of vertical shaft 11 via diagonal discharge pipe 20 while pilot gas burner 21 (which is kept lit by pilot light 22) is blasting a gas and/or other flame with excess air into discharge pipe 20 blowing upwards into discharge pipe 20 over the downwards flowing molten ash (preventing the ash from cooling off, so as to keep it flowing smoothly) and on into the bottom of the vertical shaft 11, adding heat, superheated exhaust (nitrogen, carbon dioxide, steam) plus superheated air to the solid fuel bed to react with it and produce more hydrogen, carbon monoxide, etc., which rises upward in vertical shaft 11 and adds to the other fuel gases being formed there. The fuel gases and vaporized oils/tars exit vertical shaft 11 at its top through pipe 15 with most of the vaporized oil and fuel gas going out pipe 23 to end uses as hot raw gas and/or to cooler-scrubbers or like to cool it and recover the oil to use or sell elsewhere, with the cold, fairly clean gas either going to an end use, or to further purification in a beneficator (to be discussed and described below). However some of the gas, rather than going out pipe 23, is drawn via pipe 24 together with a large amount of outside air into air blower 25 which blows both fuel gas and air into pilot gas burner 21, which as mentioned before, the flame from which, among other things, keeps the molten slag in discharge pipe 20 hot and flowing down through spout 18 into mold 19. The bottom of vertical shaft 11 is cooled externally by water jacket 28 (which generates steam to supply steam ports 16) and is supplied with water from reservoir 26, which is kept full by float valve 27. Air blower 31 supplies air to air injection ports 17 via

heat recovery channels 29 and 30 (which can be constructed of concentric shells, clusters/layers of pipe, angle iron, steel channel, etc. to cause the heat radiating out of vertical shaft 11 to be absorbed by the air going to air injection ports 11, cooling the sides of vertical shaft 11, and possibly reducing or eliminating the need to line part or all of vertical shaft 11 with refractory, as well as recycling the heat back into fuel bed 14 improving the thermal and chemical efficiency of the system.

A beneficator is merely a processor 10 as described above except that instead of steam being fed in to it via steam ports 16, gases and /or liquids containing such things as oxygenated hydrocarbons (such as organic acids and dioxins), carbon dioxide, steam, high molecular weight hydrocarbons, nitrogen oxides, sulphur oxides, etc. are fed in order to decompose them into extremely low boiling point desirable fuel gases, etc. A beneficator is normally fed with only low volatile solid fuel such as coke or char.